Turning a CO_2 Liability Into Revenue Profitably

NCF
New CO_2 Fuels

Acumentrics
TRUSTED POWER INNOVATIONS

From Challenge to Opportunity

Problem: Growing need to reduce carbon released from fossil fuel use

Pain: Increasing regulations and fees to limit fossil carbon emissions; new plants permitting depends on carbon reduction capabilities

Dilemma: Even if carbon emissions captured, storage is expensive, difficult and sometimes not permitted

Opportunity: Recycle the carbon back into fuel to displace fossil fuels

Impediment: Existing methods are expensive or limited to special situations

SOLUTION: Novel technology based on solid oxide electrochemistry and hi-temp dissociation to convert CO_2 and H_2O into fuels and chemicals at high efficiency

Who We Are

NCF
New CO_2 Fuels

- Established 2011 in Israel to develop and commercialize technology from Weizmann Institute to convert CO_2 to fuels —6 patents
- 12 people
- Privately funded (Green Earth Energy & Erdi Group)
- Recipient of BIRD Foundation funding

Acumentrics
TRUSTED POWER INNOVATIONS

- Established in 1994 in Massachusetts to develop power innovations
- 92 people
- Privately funded from individuals
- Acquired tubular solid oxide fuel cell technology in 2000, now 14 patents
- DOE and DOD funding
- 325 SOFC units in comm'l operation

Who We Will Be

"Recycled Carbon Fuels, Inc."

- US-based Joint Venture of NCF and AC in formation
- Seed funding from each parent
- Dedicated staff and management, transferred from parent companies at first
- Growing into self-sufficient independent company
- Exclusive IP licenses from parent companies plus own IP developed around perfecting RCF process

What We Need

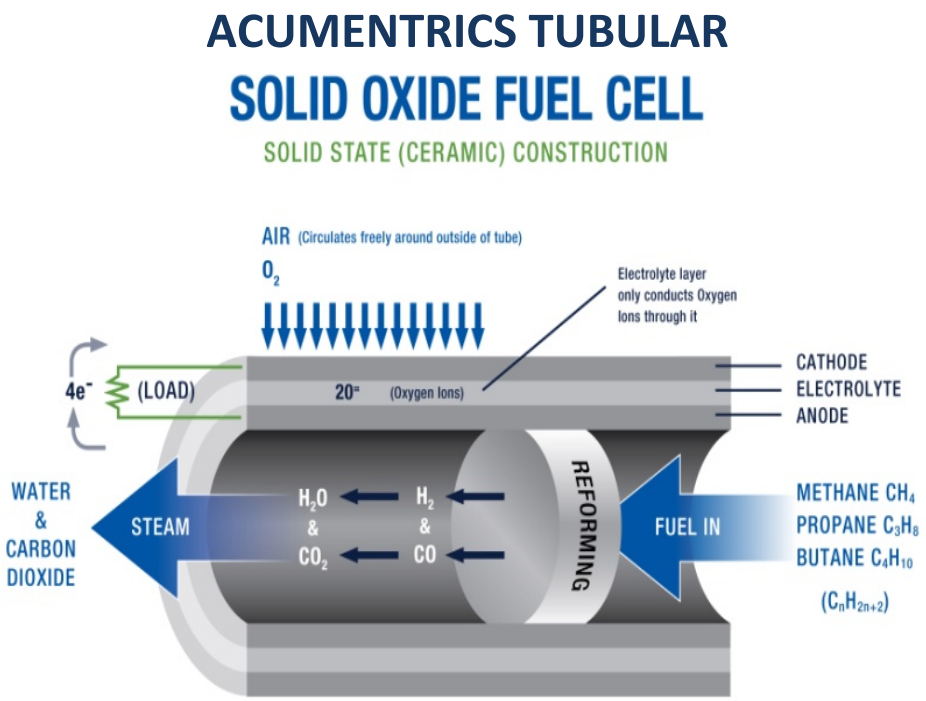
For Stepwise Business Model	Investment and Funding Sought
Develop technology and plant design through Process Development Unit (PDU)	$4 M capex + $2M opex: $3 M equity, $3 M subsidy from government agencies (BIRDF, DOE CCS & others), operate for 12-18 months
Install pilot module on host methanol or chemicals plant to prove economics over 3 years	$8 M capex + $4M net opex: $6M equity, $6M subsidy
Build and operate demonstration production units retrofit to existing plants to demonstrate profitability	$78 million for retrofit from debt, equity and subsidy. Assume majority of funding from host who benefits.
Sell basic cores for others to install on existing methanol or chemical plants or plants with sources of heat and CO2	Sales price of $56 million/core at 45% GM

$9 M investment, IRR of 40%

Acumentrics Ceramic Technology:
Key to Process Efficiency

Originally As a Power Generator

As a fuel cell, it converts carbon-based fuels into power at efficiencies far higher than any other type



Now as a Fuel Producer

As an oxygen pump, it drives the reaction to make the synthesis gas needed to make fuel and chemicals

$$CO_2 + H_2O$$

NCF/Acumentrics Technology

1000 C Heat

$$CO + O$$
$$H + H + O$$

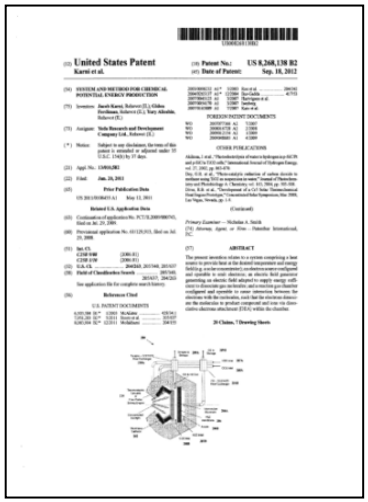
Oxygen separation

To Fuel or Chemical Synthesis

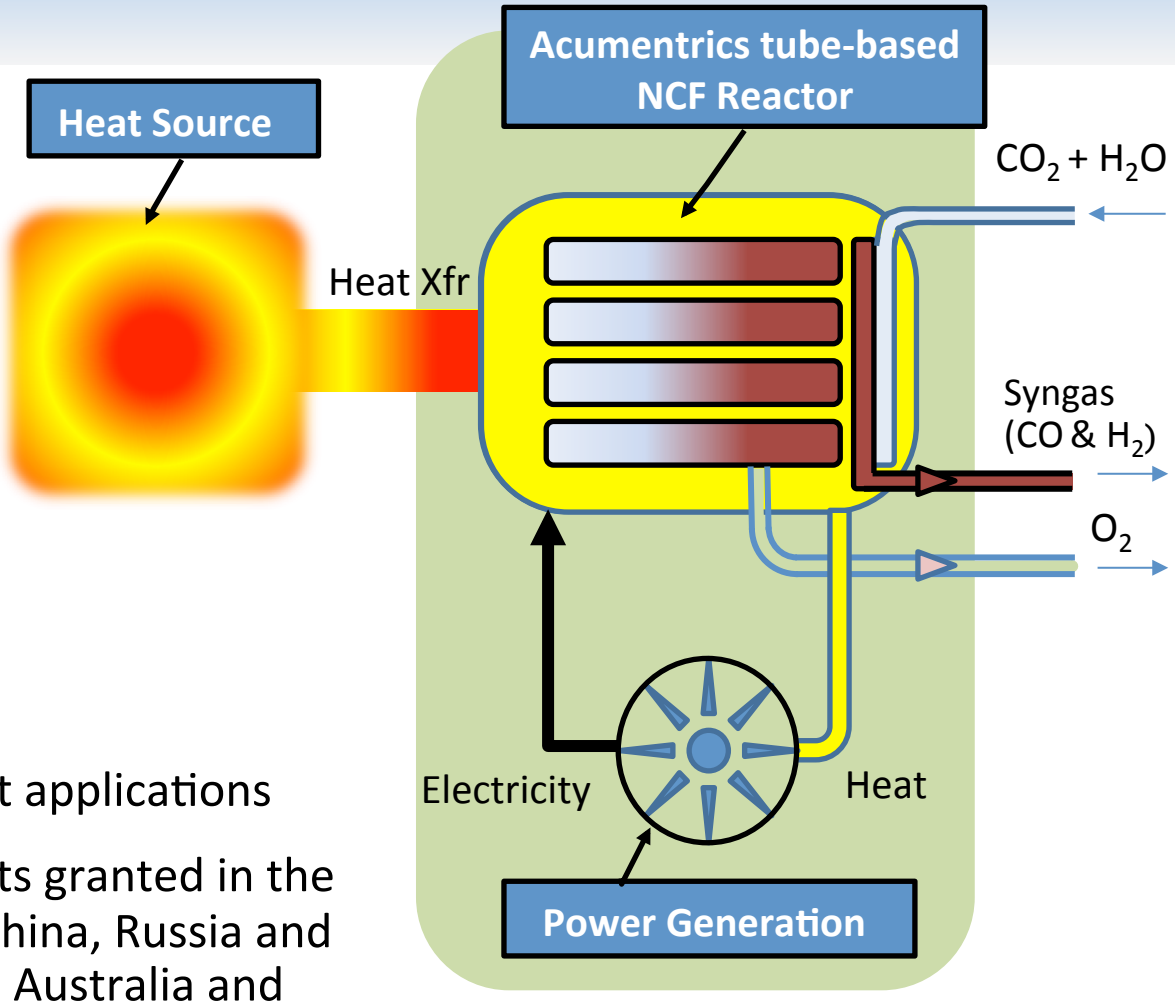
O_2

NCF and Acumentrics Deliver The RCF Technology

- **Self Sufficient system**
- **40% overall energy in/ out efficiency**
- **Clean chemical conversion process**
- **Controllable H_2:CO ratio in syngas**
- **Scalable through multiple modules**



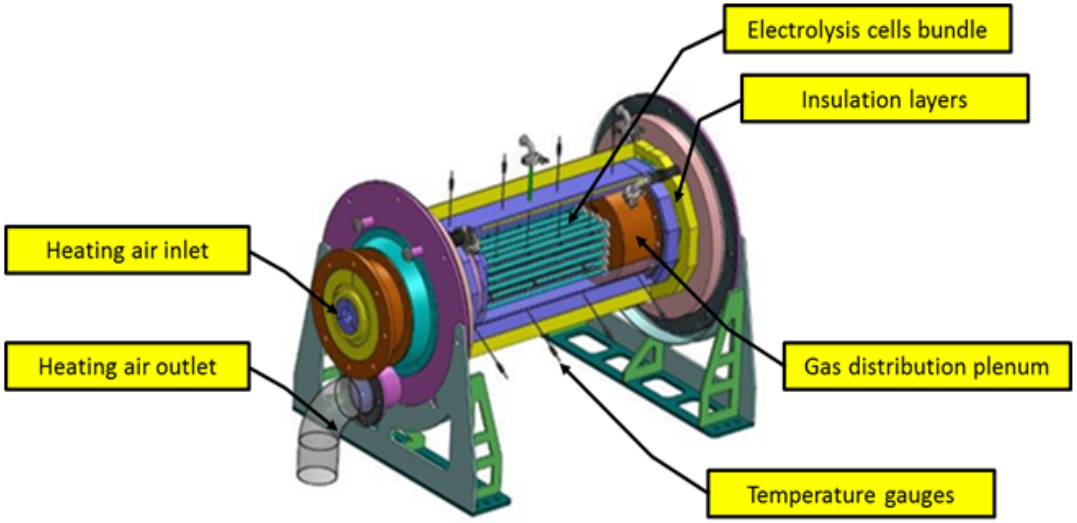
- 6 patent applications
- 2 patents granted in the U.S.A, China, Russia and Mexico, Australia and Israel
- Broad in-house know-how



1 ton CO_2 + 0.82 ton H_2O → 0.72 ton Syngas (H_2:CO - 2:1) + 1.09 ton O_2

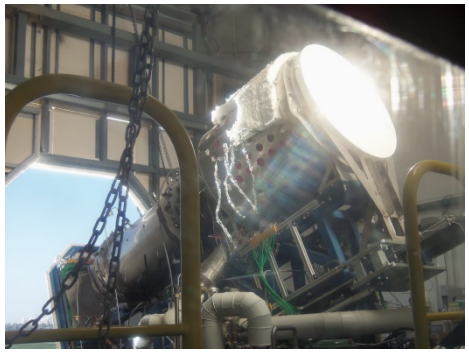
In case of methanol production - 0.72 ton Syngas (H_2:CO - 2:1) → 0.68 tons of methanol

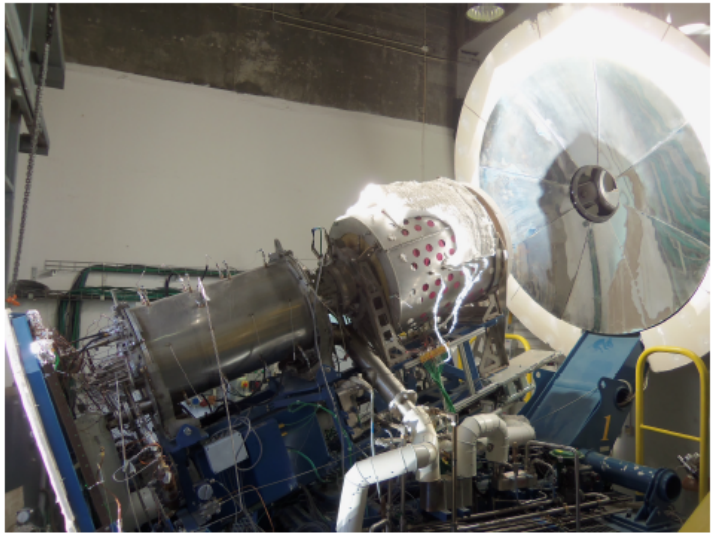
RCF Modular Reaction Core
Tube Bundles and Manifolding



- Innovation Award to NCF—World Technology Network 2014
- Designs for commercial systems validated by Worley Parsons and Technip

- Reactor proof of concept
  - with furnace simulating excess heat configuration
  - at focal point of solar receiver at Weizmann Institute





Solar dissociation of CO2 to CO & oxygen in operation using NCF's proprietary reactor and solar receiver, at the Weizmann Institute solar-tower test facility in Israel

Example of Results at Scale

Steel Plant Host, 5M tons per year

Feature	Amount	Units
Waste Heat, >1000°C	200	MWth per hour
Annual CO_2 Emissions	9,000,000	Tons per year
Heat Used	30	MWth per hour
RCF Standalone Plant CapEx	$ 217	Million
RCF Reaction Core within CapEx	$56	Million
Methanol Produced	120,000	Tons per year
Value of Methanol	$54	Million per year
CO_2 utilized	175,000	Tons per year
Oxygen Produced	180,000	Tons per year
Value of Oxygen	$11	Million per year
IRR with 80% debt (w/o subsidies)	17	Percent
Net Income to host	$7	Million per year

Hurdles and Solutions for Commercial Product

Capturing and transferring large amounts of 1000°C heat	→	Circulating molten salt working fluid
Flowing reactants and products into and out of reaction chamber simply and inexpensively	→	Simple closed-end solid oxide tube array with input/output manifold
Finding buyers for syngas nearby or manufacturing saleable liquids	→	Co-locate with syngas user that locally produces valuable chemicals/fuels

Market Entry Strategy

First Market = Retrofit at Methanol Plant

- Easy to add to existing methanol plants as side stream process
- Plants already need synthesis gas—most reform natural gas to synthesis gas, then into methanol converter
- Plants have everything else that is needed
- Gasification provides high heat and high purity CO2 stream

- 90+ methanol plants worldwide
- Annual demand 75 million MT/year
- Expect 140 million MT/yr by 2020
- Existing plant sizes from 10K-850K MT/yr
- Expected size of RCF plant = 120,000 MT/yr
- Provides supplemental source of synthesis gas

Second Market = Retrofit at Industrial Plants

Industrial excess heat market, worldwide	Waste Heat Temp. °C	Available heat (MWth/year)	MT Methanol if 15% of heat used	Metric Tons of CO2 Avoided
Steel	1200-1700	130 million	9.75 million	14.6 million
Aluminum	1100	80 million	6.0 million	7.5 million
Glass	1375	30 million	2.25 million	3.4 million
Coal IGCC plants (assume 10)	1000	20 million	1.5 million	2.3 million

20 Million MT Methanol = 165 cores = Revenue potential of $9 billion

Superior to Competitors

- Many pursuing photosynthesis, but very inefficient (<4%)
- Carbon Recycling International, Cerametec, Sunfire, and Carbon Engineering & Airfuel Synthesis all use electrolysis
  - Need 32 kWh of power for $1 of product vs. 2 kWh for RCF
  - Uneconomic if power costs > 2 ¢ per kWh
  - Viable only in limited special circumstances without subsidies due to power costs
  - CRI alone is commercially viable due to access to geothermal power and trapped CO_2 in Iceland, plus subsidy for renewable-sourced methanol in Europe
  - All less than 10% efficient converting energy input to fuel energy
- RCF technology uses heat, available worldwide, no limits
- No subsidies needed for profitable operations
- RCF process 40% efficient and can make multiple products

Summary

- Novel technology to convert carbon dioxide and water back into valuable products
- Relies on thermal dissociation with waste heat and minimizes use of electricity to achieve high efficiency, low OpEx
- Profitable at today's prices, substantial market potential
- Experienced commercial teams in parent companies
- Seeking $9 million in equity to create JV to advance technology through pilot plant operation over 4 years and then manufacture cores
- Returns through sale of basic reaction cores at 45% gross margin starting in 2020

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